Fast Prediction of RF Fields in the Human Brain

Jay Moore[1,2], William A. Grissom[1,3], and John C. Gore[1,2]
[1]Vanderbilt University Institute of Imaging Science, Vanderbilt University, Nashville, TN, United States, [2]Department of Radiology and Radiological Sciences, Vanderbilt University, Nashville, TN, United States, [3]Department of Biomedical Engineering, Vanderbilt University, Nashville, TN, United States

Introduction

Patient-specific mapping of the transmitted RF field (B_1^+) is currently requisite for multi-channel RF shimming as well as for many RF pulse designs that compensate for B_1^+ heterogeneity in MRI systems with either single- or multi-channel transmission capabilities. The primary purpose of this research is to investigate a technique that could eliminate the pre-calibration step of measuring B_1^+ by predicting RF fields from the physical shape of the imaging volume. This approach is highly significant in that it could drastically accelerate the pre-scan workflow at high-field, thus bringing ultra-high-field MRI considerably closer to clinical deployment. To date, our research has been carried out only in the context of 7 T MRI of the human brain; however, similar strategies may prove useful for imaging other anatomy and at different field strengths.

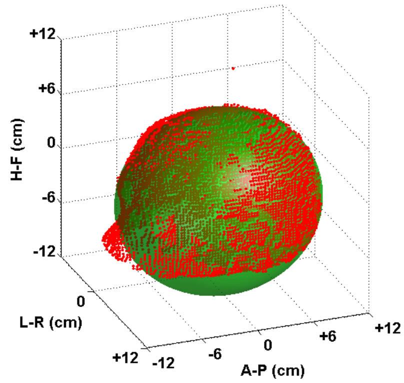

Fig. 1: Flesh-air interface of the head (red data points) and a fitted ellipsoid (green). The B_1^+ prediction method is based on the matching of ellipsoid eigenvectors to those in an atlas.

Methods

Our procedure for predicting RF fields begins with the acquisition of an *atlas* of 7 T RF field maps [1] in the brains of 20 subjects along with typical survey scans and whole-brain B_0 maps acquired via a dual-echo, 3-D FFE sequence with 3mm isotropic resolution (~20 s duration). Anatomical data from the first echo are used to determine the basic geometry of each subject's head—a step accomplished through fitting an ellipsoid to the flesh-air interface (Fig. 1). The whole-head images and associated B_1^+ maps are then registered to a designated reference using established rigid-body registration methods [2]. For any new patient, a B_0 scan is used to determine basic head shape by the same means. A numerical minimization algorithm then determines which head from the atlas is the best geometrical match, and the corresponding B_1^+ map from the atlas is rigidly registered to the patient's head. Evaluation is based on comparison of measured and predicted B_1^+ maps and the corresponding performance of RF pulses.

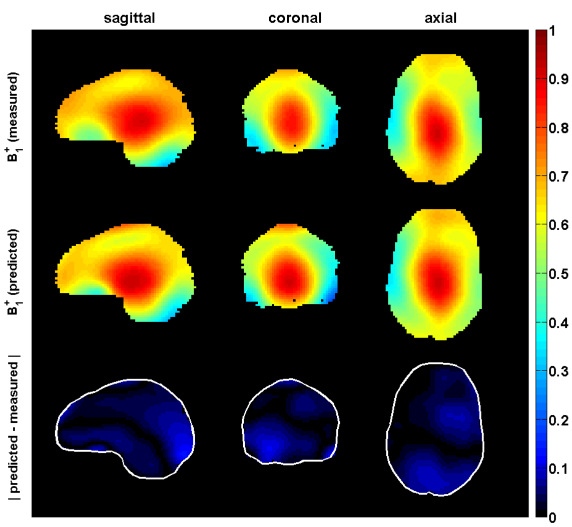

Fig. 2: Actual B_1^+ maps measured in vivo at 7 T (top); predicted maps (middle); the absolute difference in the two is expressed in the units of the nominal B_1^+ strength (bottom).

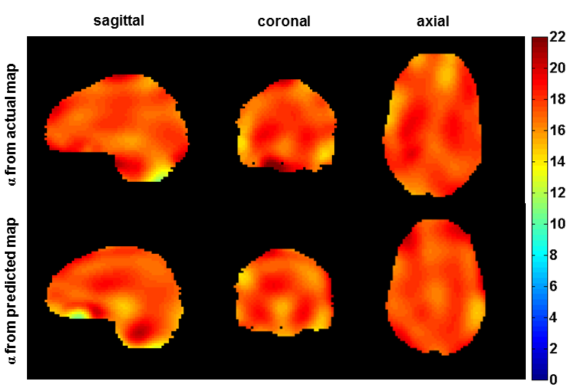

Fig 3: Simulated flip-angle maps (in degrees) using a 9 k_T-point pulse design. Flip-angle maps resulting from measured B_1^+ maps (top row) and those resulting from the predicted B_1^+ maps (bottom row) exhibit slight differences in the spatial excitation patterns but a similar degree of flip-angle homogeneity.

Results and Discussion

Preliminary results demonstrate that spatial B_1^+ intensity can be predicted with high accuracy via the proposed technique. The striking similarity between actual and predicted B_1^+ field maps in a given subject is evident in Figure 2, with a whole-brain mean difference of 5.5±4.7%. This level of variation is far less than that observed when using different field mapping techniques in the same subject [3]. The influence of B_1^+ field prediction on RF pulse efficacy is demonstrated through performance evaluation of k_T-points pulses [4] designed using the actual and predicted B_1^+ maps for a single subject (Fig. 3). Pulses designed from predicted maps are then used in flip-angle simulations based on the measured field maps. The results suggest that pulses designed from predicted B_1^+ maps may vary slightly in the specific patterns of excitation but nevertheless achieve a similar degree of flip-angle homogeneity.

Accurate RF field prediction would undoubtedly have a high impact on the workflow of MR systems whenever knowledge of the RF fields is required. For example, RF shim coefficients or B_1^+-compensating pulse designs (e.g. spokes pulses) could be calculated while forgoing the time-consuming step of B_1^+ mapping. Pulses or shim values, having been previously designed for each of the field maps of the atlas, could even be used to entirely avoid the process of real-time RF calibration. Furthermore, the proposed B_1^+ prediction methods are likely to prove useful in the context of SAR prediction. Such accomplishments would clear several major hurdles pertaining to the practical clinical use of ultra-high-field MRI.

Conclusion

A method of estimating B_1^+ distributions in the human brain at 7 T has been described and validated through simulation. The approach is shown to predict whole-brain B_1^+ fields with high accuracy and with computational times of <1 s, making it a viable and attractive alternative to conventional subject-specific B_1^+ mapping in high-field MRI.

Acknowledgments: This work was supported by NIH grant 5T32EB001628-09.

References: [1] Hornak, J. et al., *Magn. Reson. Med.* 6:158 (1988); [2] Viola, P. et al., *Int. J. Comput. Vision* 24:137 (1997); [3] Moore, J. et al. *Proc. Int. Soc. Magn. Reson. Med.* 17:372 (2009); Cloos, M. et al., *Magn. Reson. Med.* 67:72 (2012).